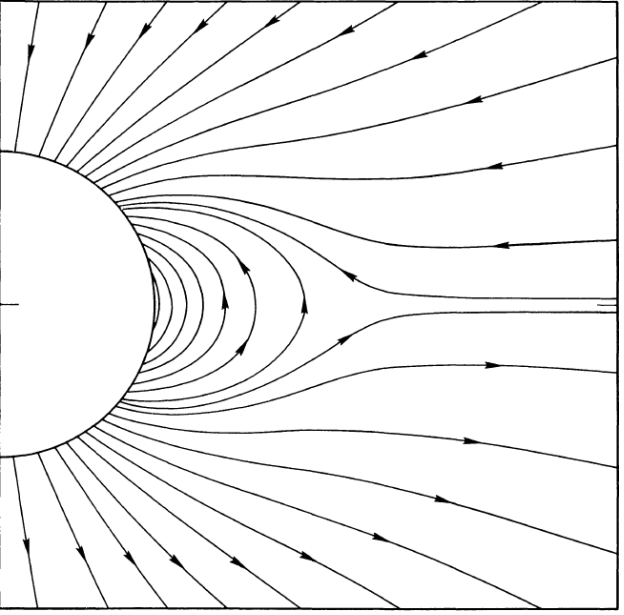
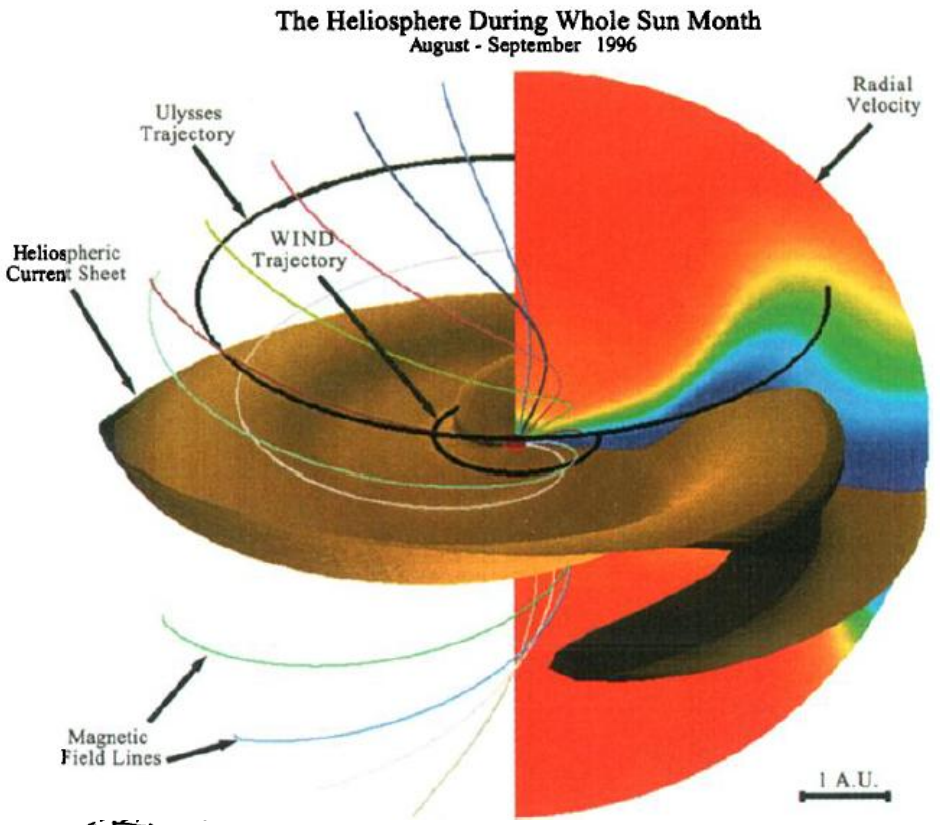
Magnetic clouds and Heliospheric Current Sheet

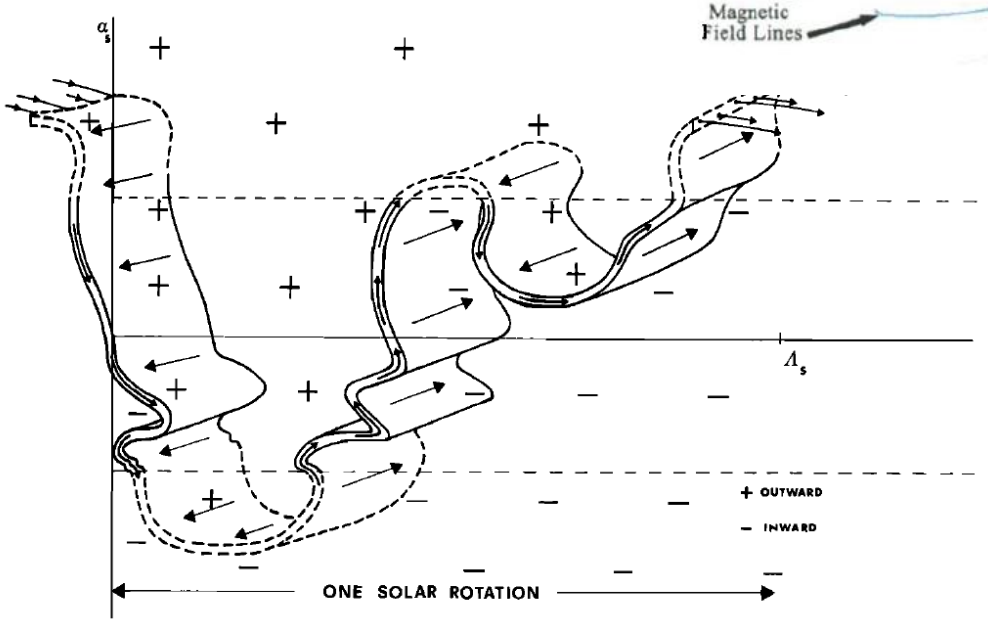
JJ. Blanco, M.A. Hidalgo, J. Rodriguez-Pacheco and J. Medina



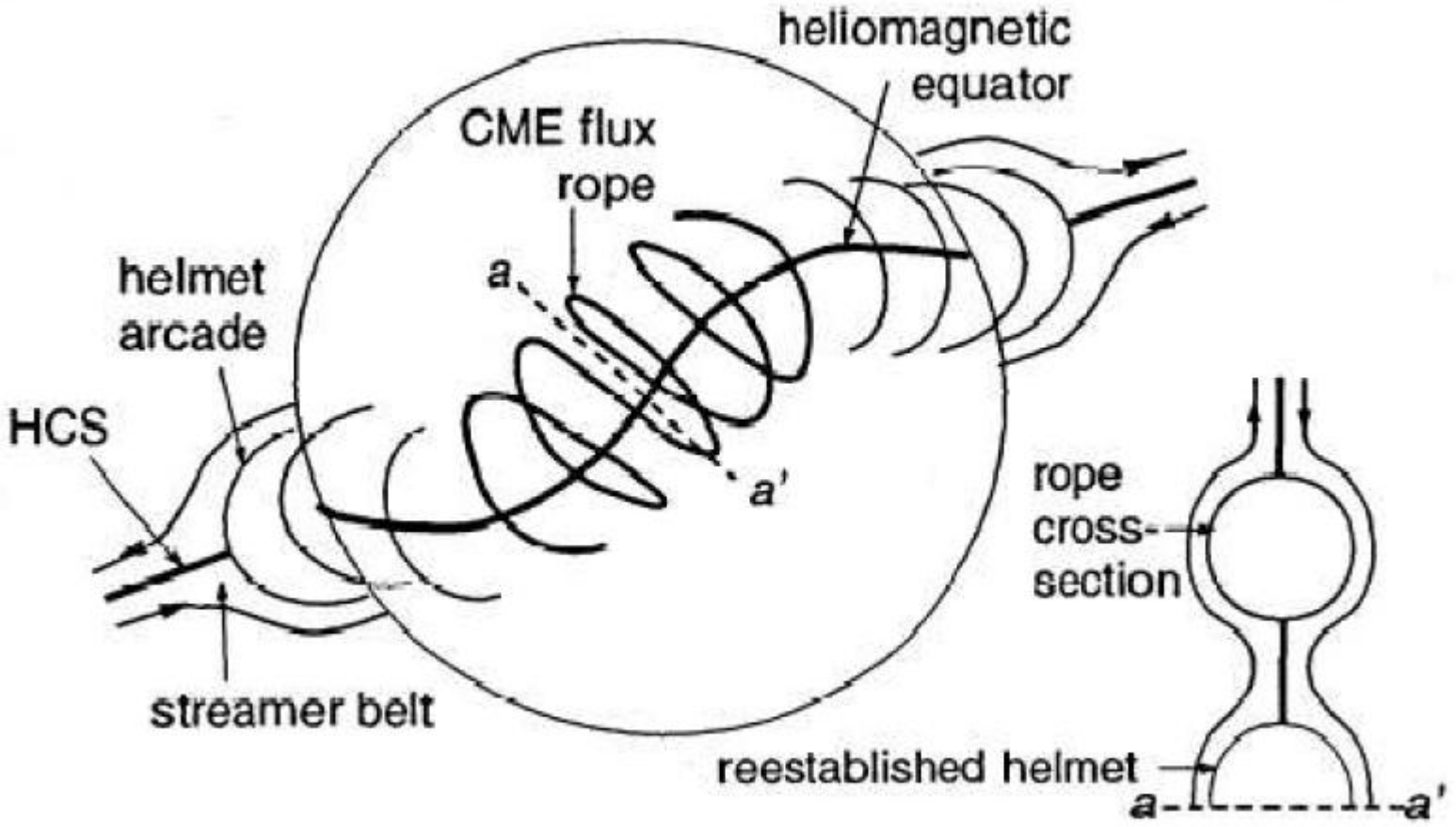
Schulz, M. 1973



Riley et al., 2001



Villante, et al., 1979



Crooker *et al., 1998*

1. MC study
2. HCS study
3. HCS normal vector projection on the solar surface plot
4. Neutral line elevation
5. Relative MC and HCS orientation

Hidalgo's model (An analytical non-force-free model $\vec{j} \times \vec{B} \neq 0$

PHYSICAL CONDITIONS

Non force-free character Cylindrical geometry with an elliptic cross section

$$x = a\cosh\eta\cos\varphi$$
$$y = y$$
$$z = a\,\mathrm{senh}\,\eta\,\mathrm{sen}\,\varphi$$

Linear time dependence of the plasma current density

$$B_\eta = 0$$
$$B_y = B_y^0 + \mu_0\alpha(t_0 - t)\,\mathrm{rSE}(\cos\varphi, 1/\cosh\eta)\cosh\eta$$
$$B_\varphi = -\frac{\mu_0\lambda(t_0 - t)\,r\cosh\eta}{\left[\cosh^2\eta - \cos^2\varphi\right]^{\frac{1}{2}}}$$

Magnetic field components in the GSE coordinate system

$$B_x^{GSE} = B_x\cosh\eta(\cos\phi\cos\zeta - \sin\zeta\sin\phi\sin\theta) - B_y\sin\phi\cos\theta + B_z\sinh\eta(\cos\phi\sin\zeta + \cos\zeta\sin\phi\sin\theta)$$
$$B_y^{GSE} = B_x\cosh\eta(\sin\phi\cos\zeta + \sin\zeta\cos\phi\sin\theta) + B_y\cos\phi\cos\theta + B_z\sinh\eta(\sin\phi\sin\zeta - \cos\zeta\cos\phi\sin\theta)$$
$$B_z^{GSE} = -B_x\cosh\eta\sin\zeta\cos\theta + B_y\sin\theta + B_z\sinh\eta\cos\zeta\cos\theta$$

where
$$B_x = -(r/h)B_\varphi\,sin\varphi$$
$$B_z = (r/h)B_\varphi cos\varphi$$

PARAMETERS OF THE MODEL

- *Parameters related to orientation of the cloud*:

the latitude with respect to the ecliptic plane, θ,

the longitude in the ecliptic plane, ϕ,

the minimum distance of the spacecraft to the cloud axis, *y*0

the cross-section orientation, ζ

- *Parameter related to the plasma behavior*: $\alpha\ \lambda$

- Parameter related to the distortion of the cross section of the cloud: η

*- Parameter related to the expansion of the cross section of the cloud: t*0

*- The axial component of the magnetic field at the axis of the cloud B****y0***

Determining the Heliospheric Current Sheet Orientation

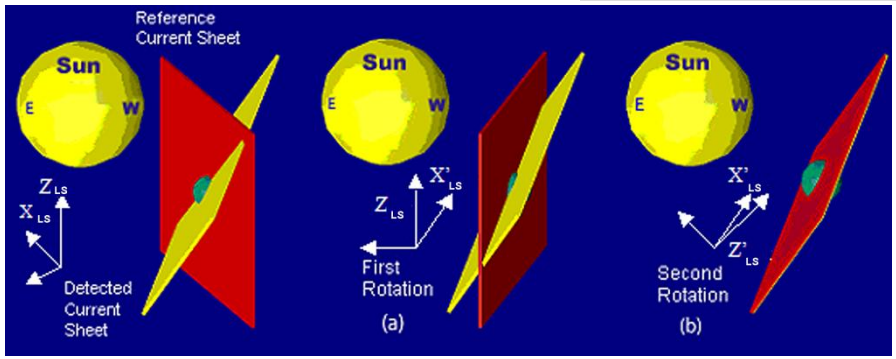
Minimum Variance Analysis (MVA)

- Variance matrix
- minimum eigenvector defines the normal to the HCS local plane
- Medium and minimum eigenvalues ratio > 10

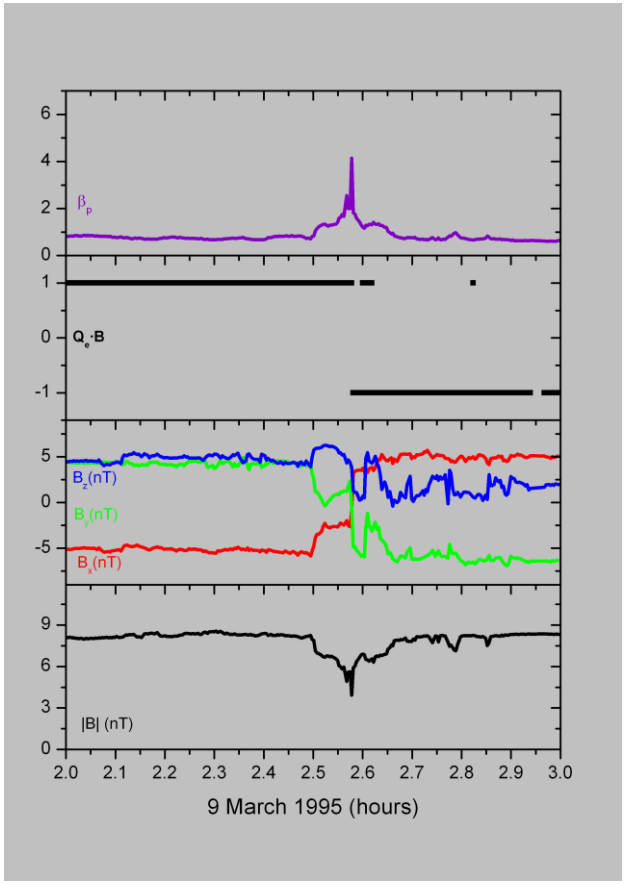
HYTARO

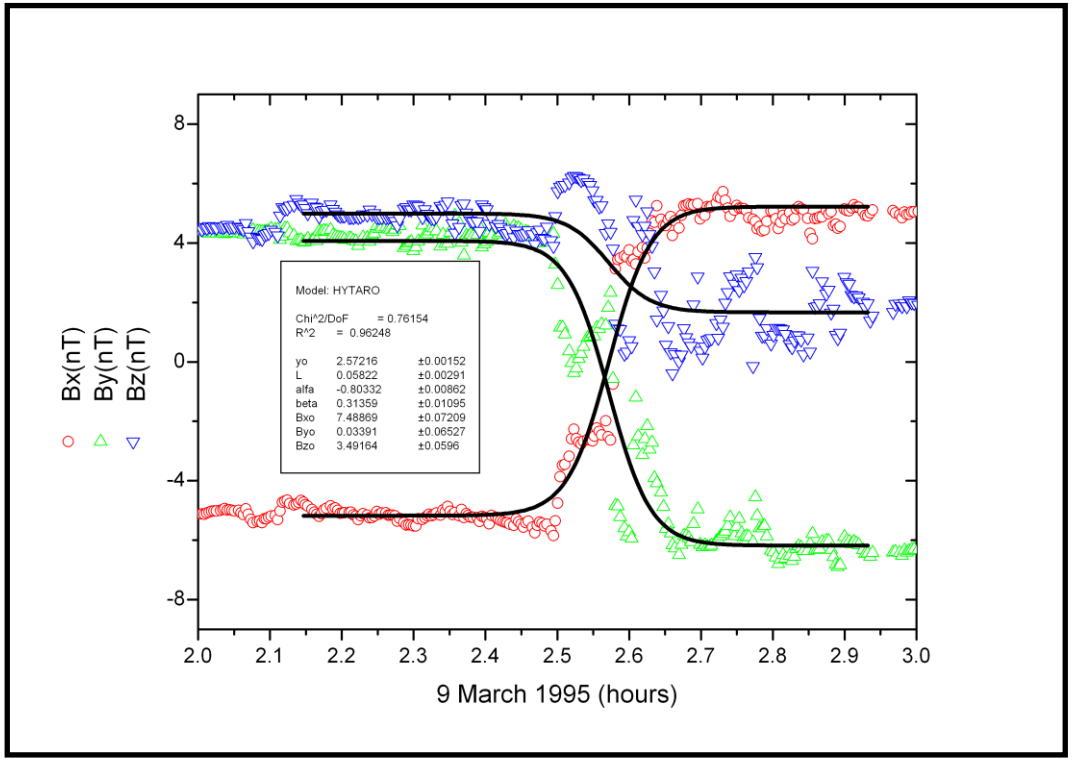
$$B_x = B_{x0}\tanh\left[\frac{(y-y_0)}{L}\right]$$
$$B_y = B_{y0}$$
$$B_z = B_{z0}$$

$$B_x^{GSE} = B_{x0}\tanh\left[\frac{(y-y_0)}{L}\right]\cos\alpha - B_{y0}\sin\alpha$$
$$B_y^{GSE} = B_{x0}\tanh\left[\frac{(y-y_0)}{L}\right]\sin\alpha\cos\beta + B_{y0}\cos\alpha\cos\beta - B_{z0}\sin\beta$$
$$B_z^{GSE} = B_{x0}\tanh\left[\frac{(y-y_0)}{L}\right]\sin\alpha\sin\beta + B_{y0}\cos\alpha\sin\beta + B_{z0}\cos\beta$$



Example of HCS crossing

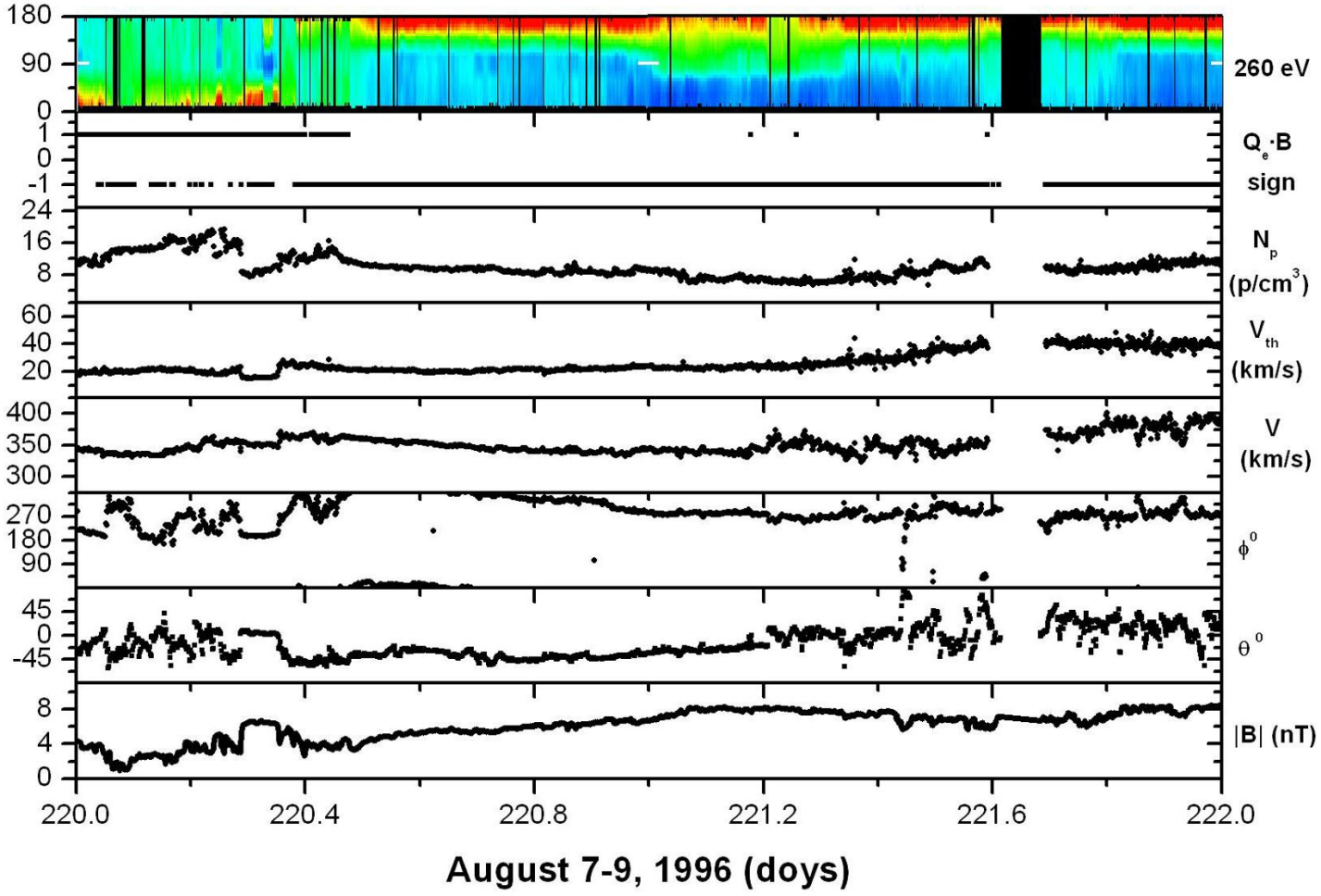


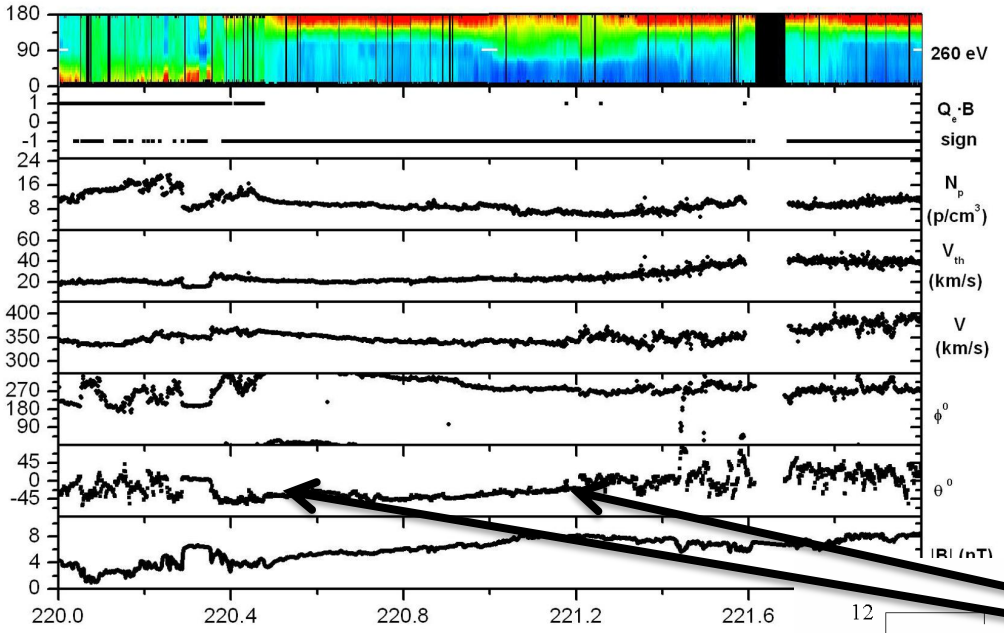


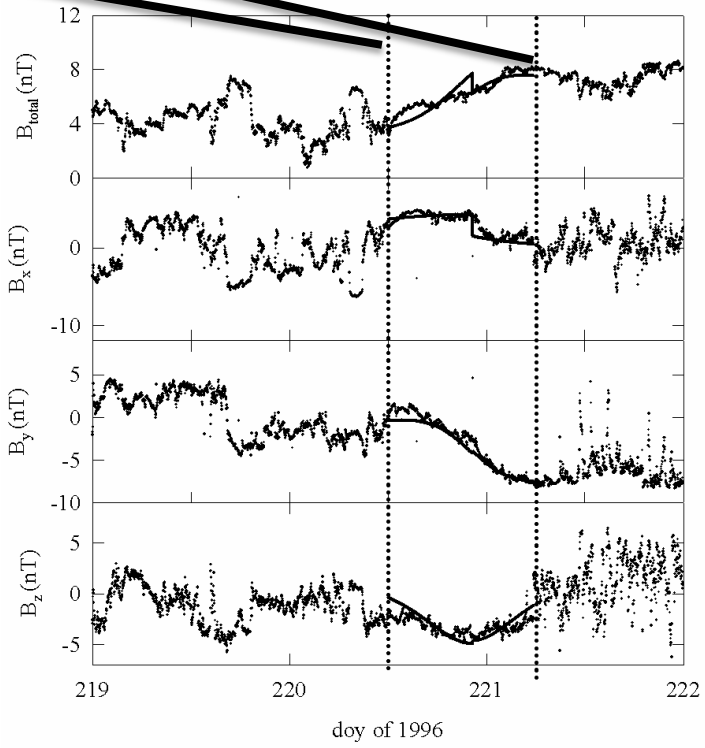
HYT: (0.72, 0.66, 0.21)

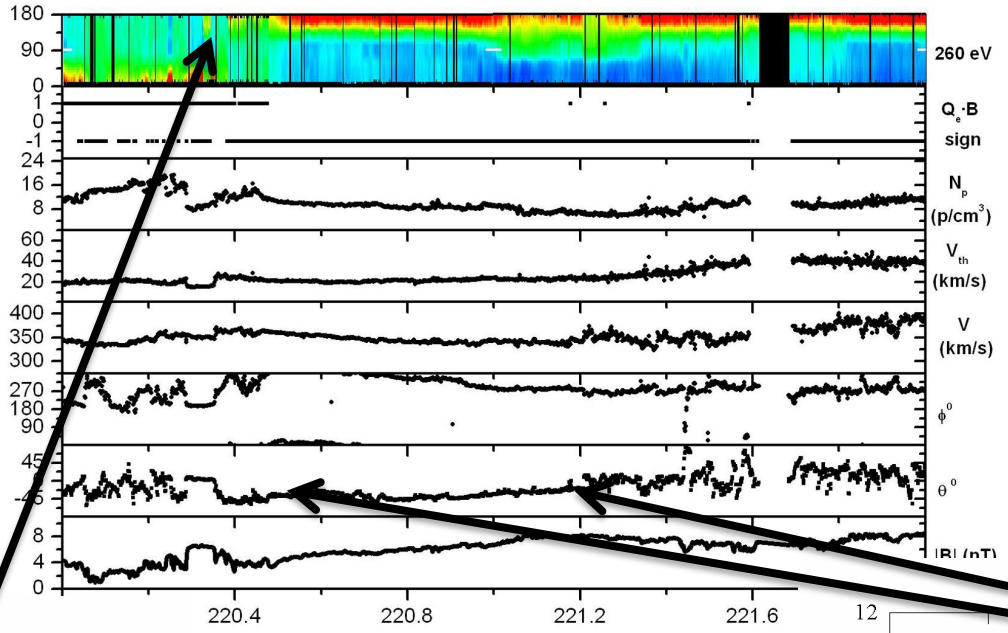
MVA: (0.67,0.73,-0.16) with $\lambda_2/\lambda_3 = 3.2$

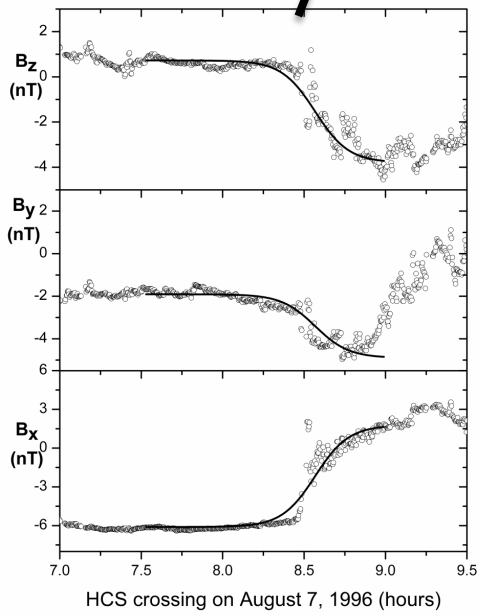
MC and HCS crossing: Example 1

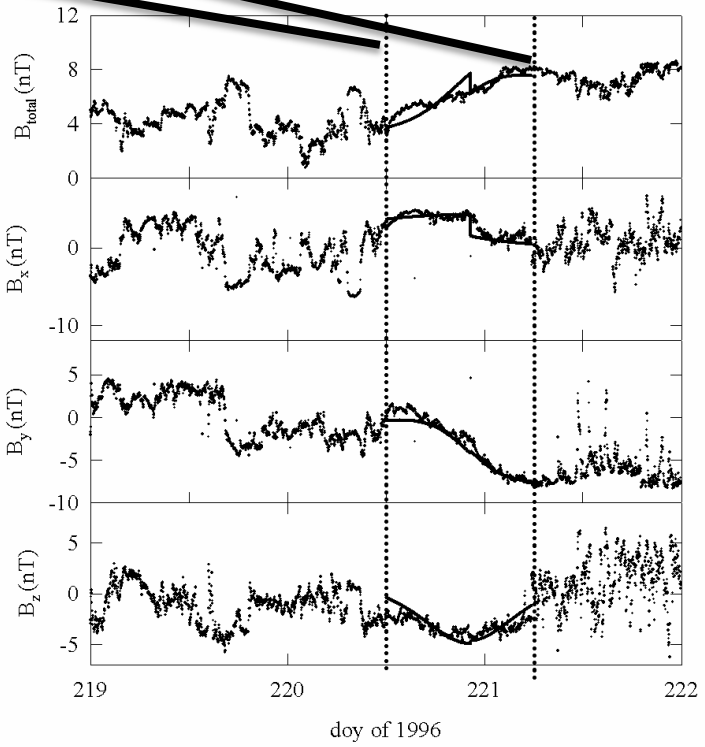



180
90
0
260 eV
1
0
-1
$Q_e \cdot B$
sign
24
16
8
N_p
(p/cm^3)
60
40
20
V_{th}
(km/s)
400
350
300
V
(km/s)
270
180
90
ϕ^0
45
0
-45
θ^0
8
4
0
|B| (nT)
220.0
220.4
220.8
221.2
221.6
August 7-9, 1996 (doys)


12
8
4
0
B_{total} (nT)
0
-10
B_x (nT)
5
0
-5
-10
B_y (nT)
5
0
-5
B_z (nT)
219
220
221
222
doy of 1996


260 eV
Q_e·B sign
N_p (p/cm^3)
V_th (km/s)
V (km/s)
ϕ°
θ°
|B| (nT)
220.4
220.8
221.2
221.6
August 7-9, 1996 (doys)

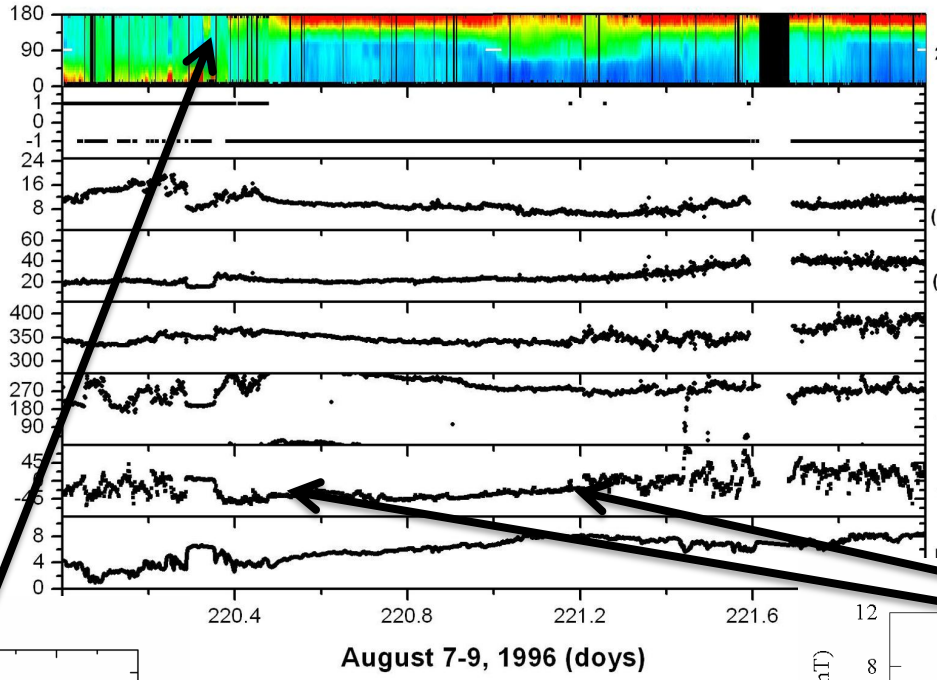

B_z (nT)
B_y (nT)
B_x (nT)
7.0
7.5
8.0
8.5
9.0
9.5
HCS crossing on August 7, 1996 (hours)


B_total (nT)
B_x (nT)
B_y (nT)
B_z (nT)
219
220
221
222
doy of 1996

HYT(0.56,0.46,0.69)

MVA(0.52,0.51,0.69)

with eigenvalues ratio of 1.9

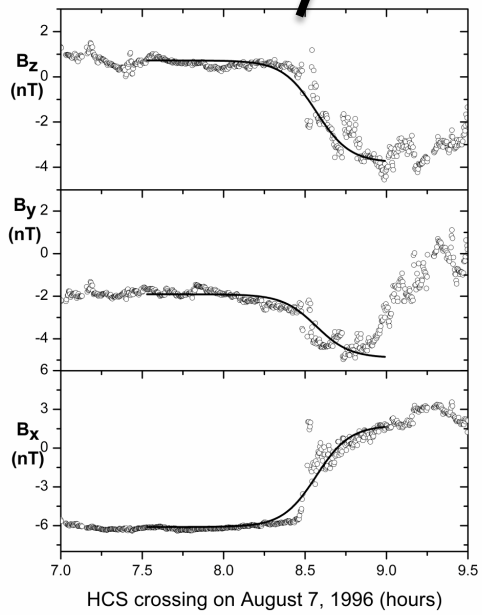


This HCS crossing was connected with a neutral line portion placed on the Sun–Earth line six days before

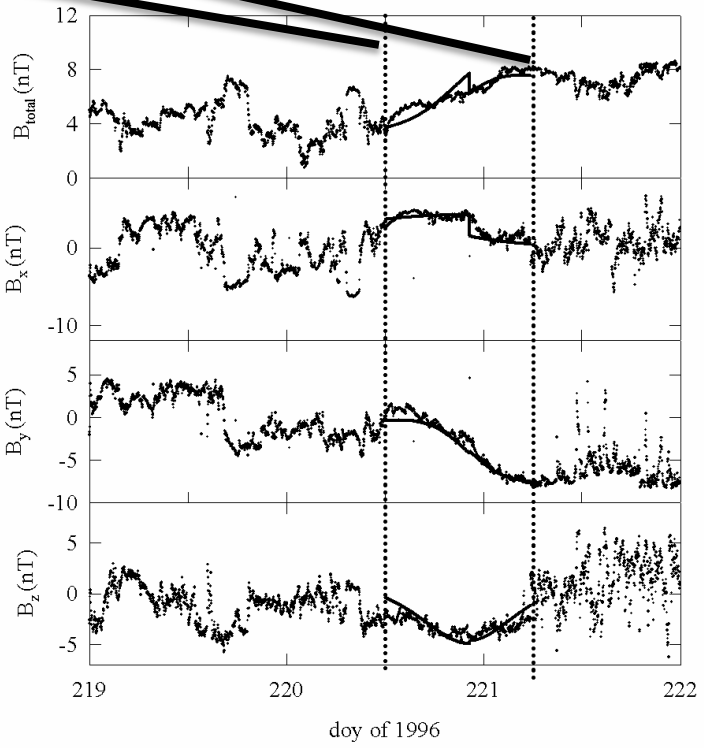
The angle between the HCS projection and the neutral line was **76º**

The difference between the neutral line inclination and the MCaxis was **55º**.

At 1 AU, the angle between the MC axis and the HCS normal vector was estimated to **64º**.



- Elapsed time 3.4 h
- MC axis (0.1,0.99,0.1)
- Helicity –
- Solar source CME observed by C2-SOHO at a position angle of 231º



HYT(0.56,0.46,0.69)

MVA(0.52,0.51,0

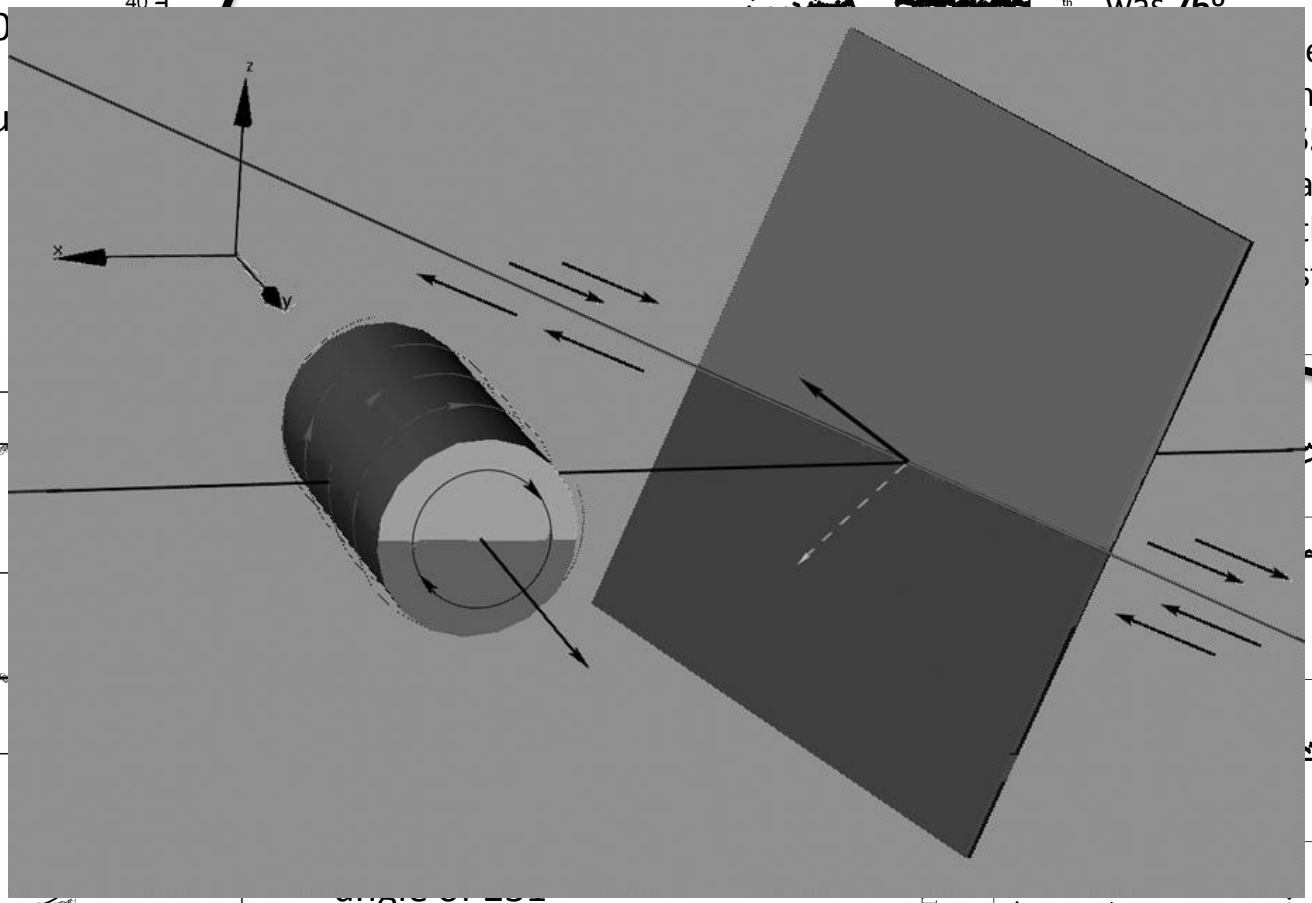
with eigenvalu
ratio of 1.9

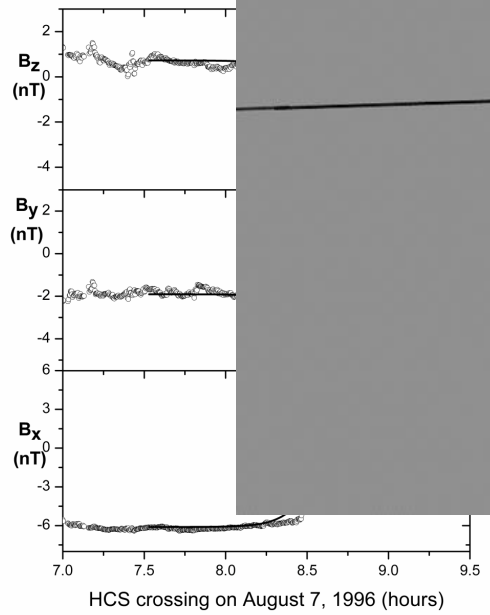
This HCS crossing was connected with a neutral line portion placed on the Sun–Earth line six days before

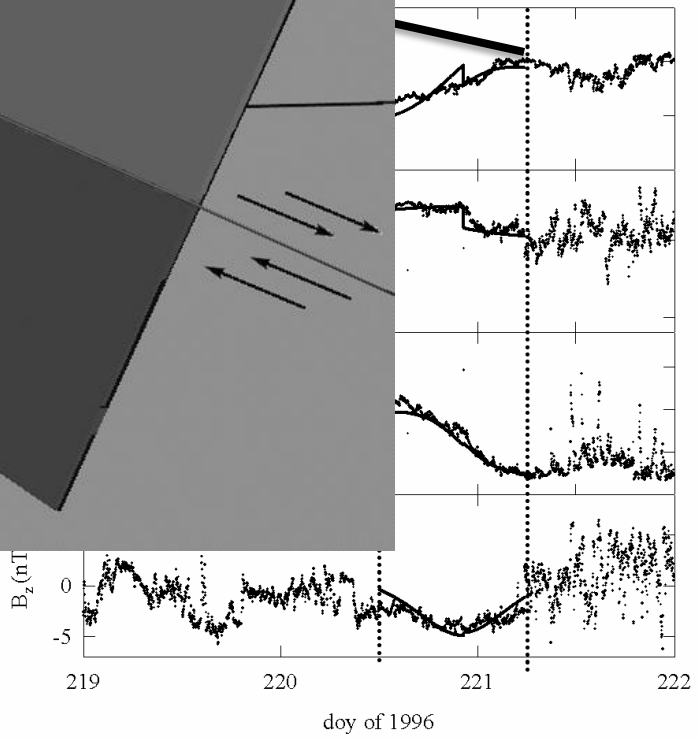
The angle between the HCS projection and the neutral line was **76º**.

e between the
nclination and the
5º.

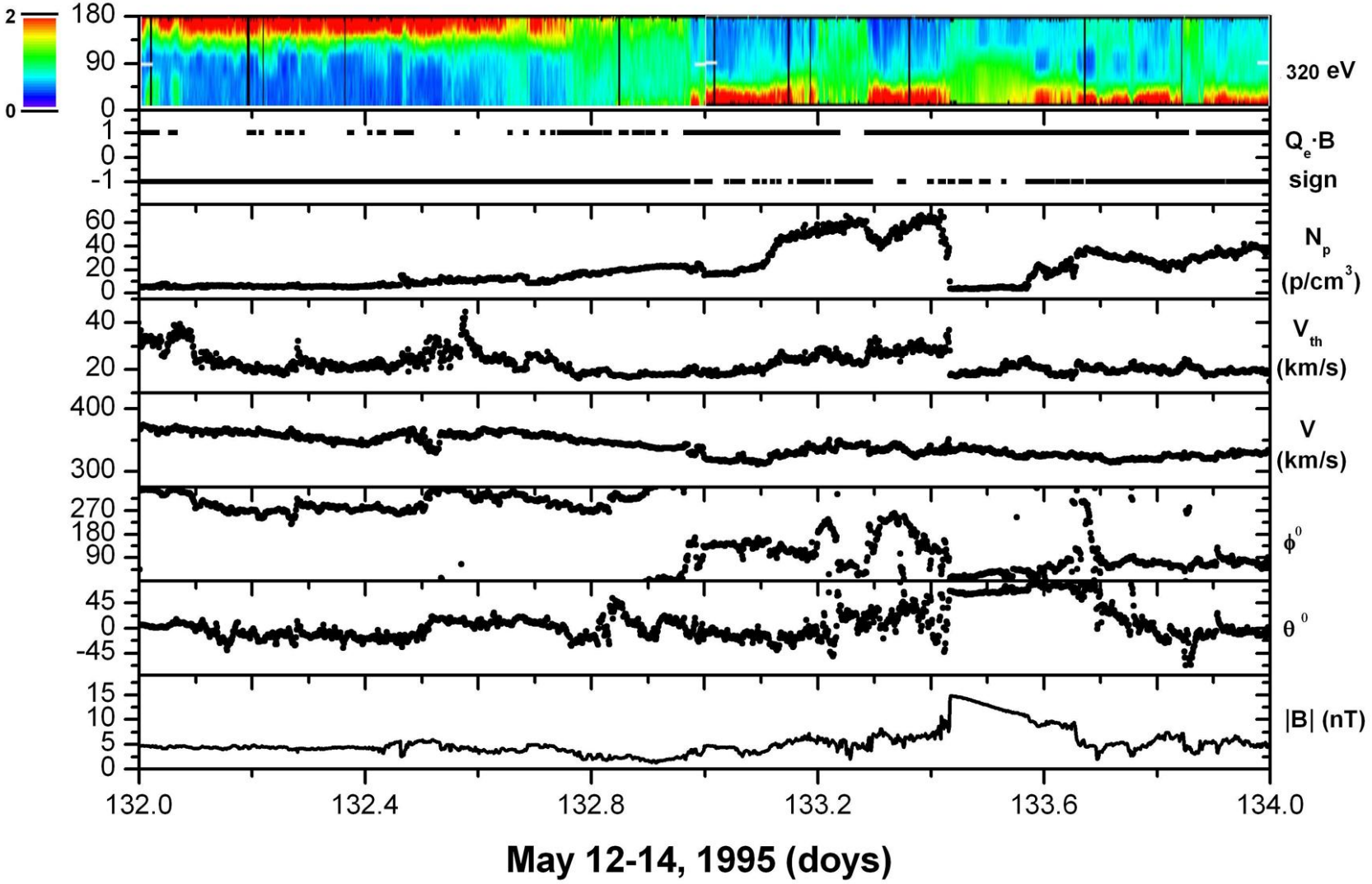
angle between the
the HCS normal
stimated to **64º**.

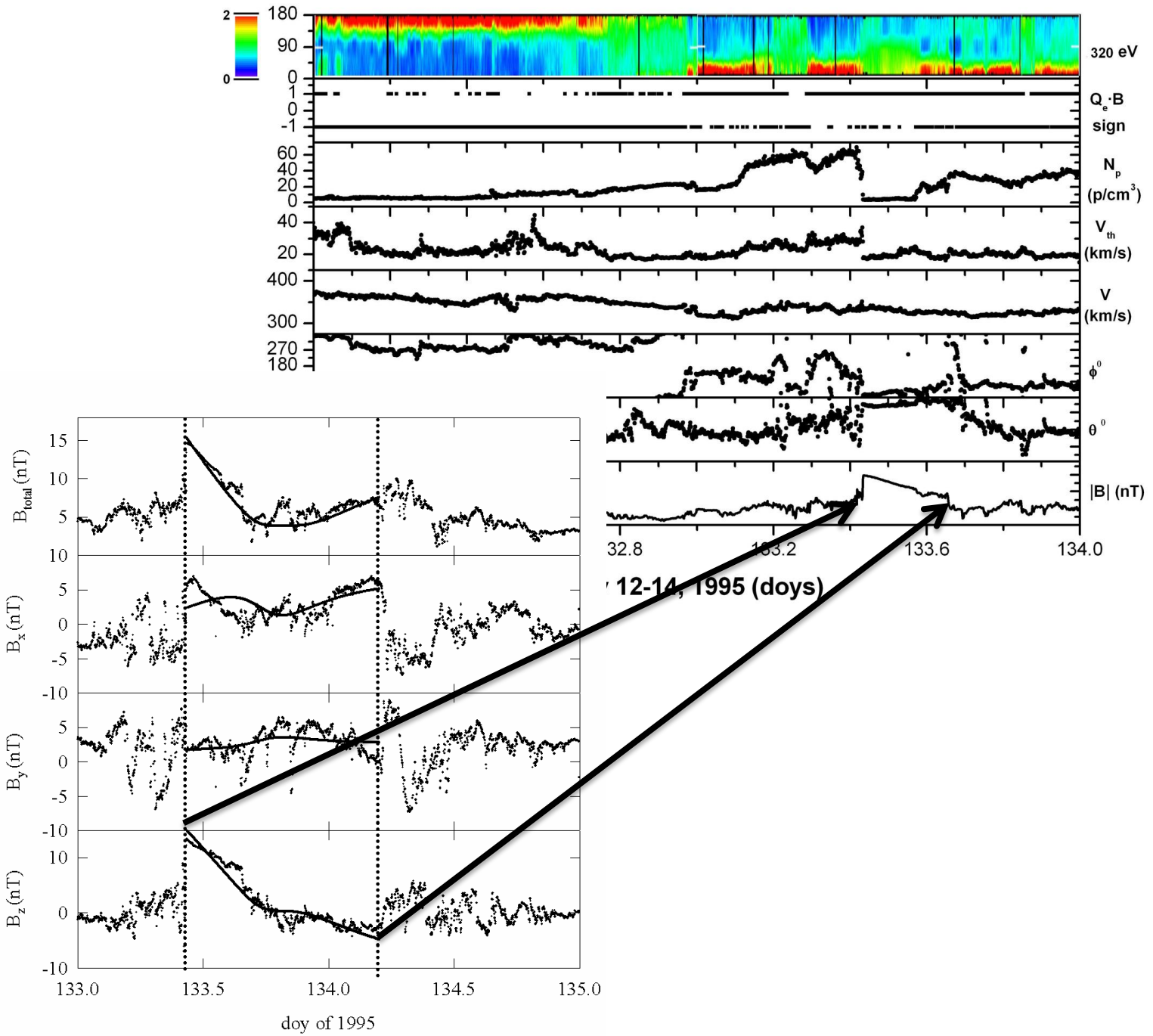


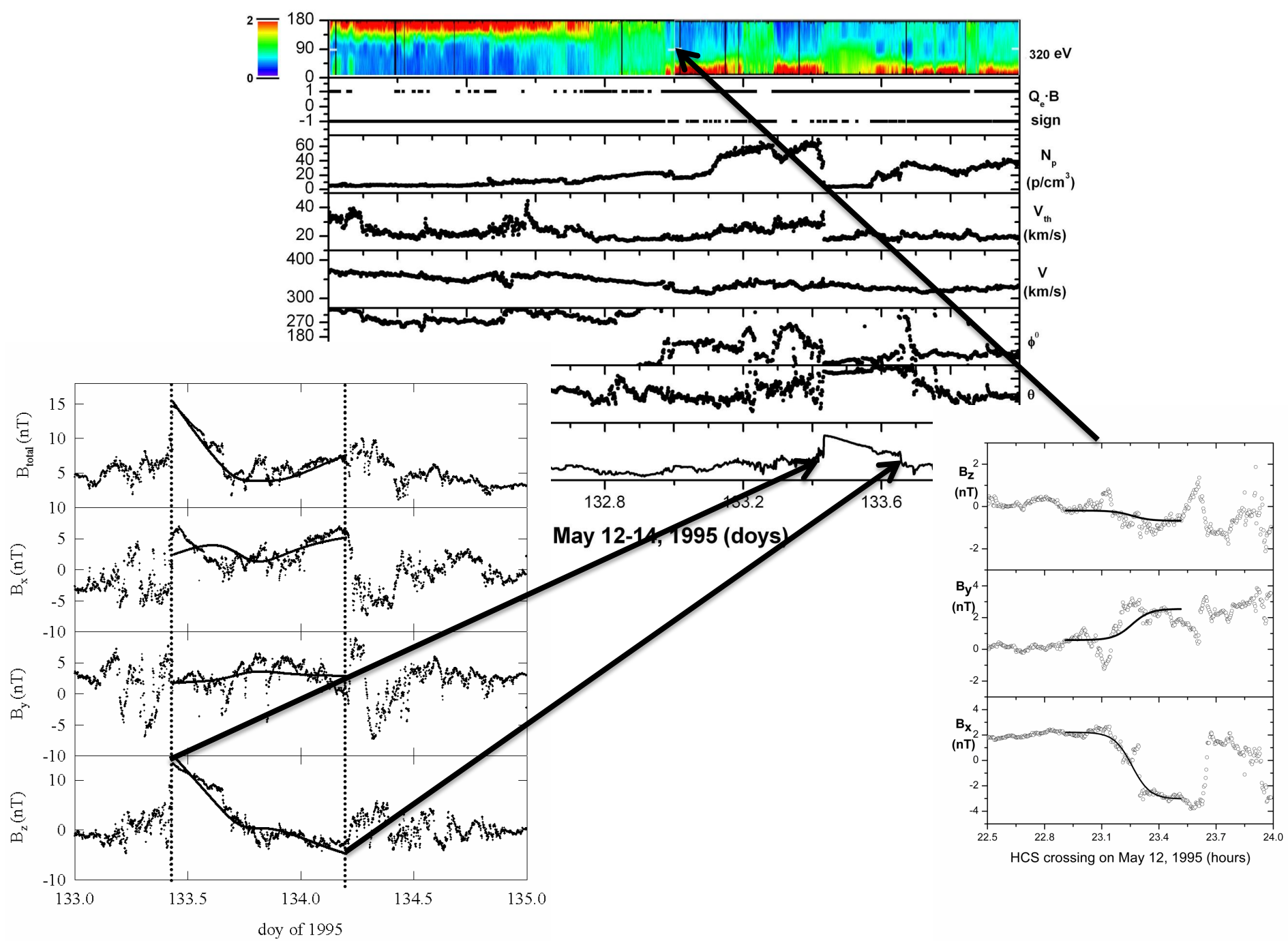




MC and HCS crossing: Example 2



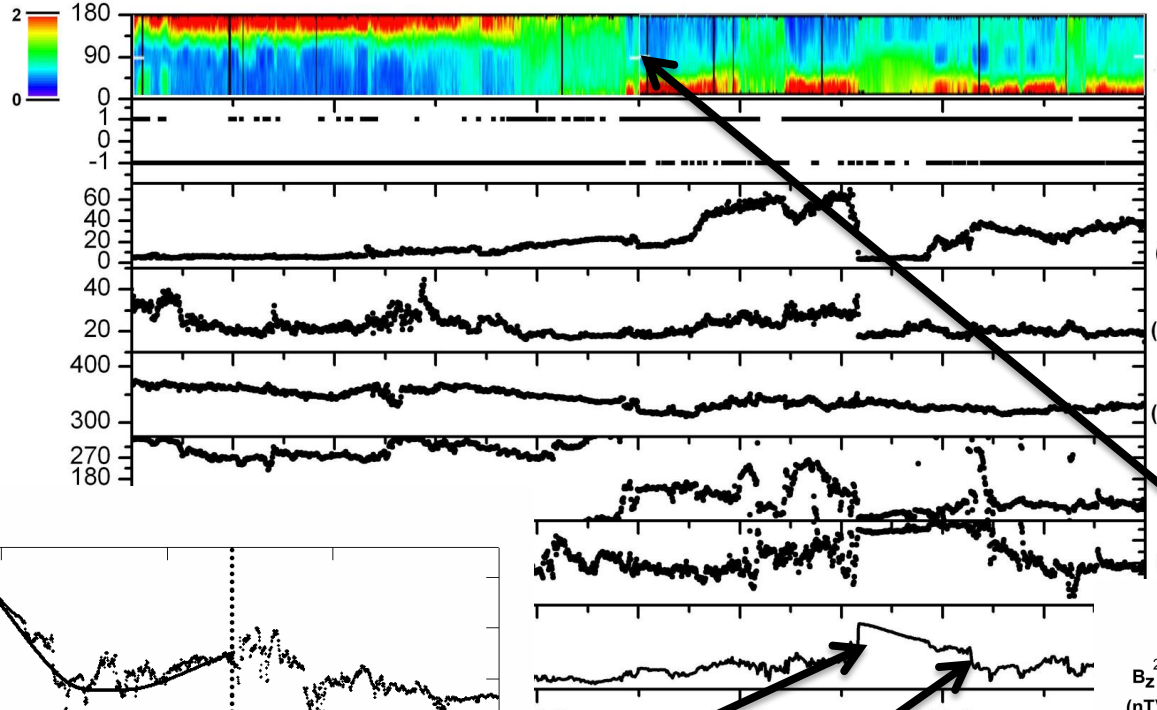

320 eV
Q_e·B sign
N_p (p/cm^3)
V_th (km/s)
V (km/s)
φ^0
θ^0
|B| (nT)
32.8
133.2
133.6
134.0
12-14, 1995 (doys)
B_total (nT)
B_x (nT)
B_y (nT)
B_z (nT)
133.0
133.5
134.0
134.5
135.0
doy of 1995

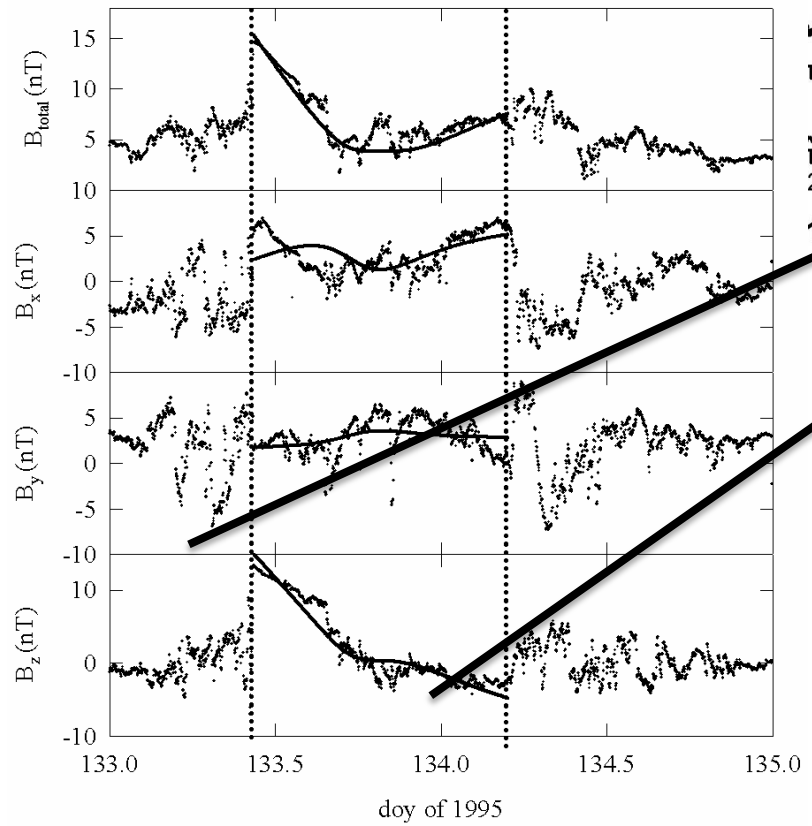

320 eV
Q_e·B sign
N_p (p/cm^3)
V_th (km/s)
V (km/s)
φ^0
θ
132.8
133.2
133.6
May 12-14, 1995 (doys)
B_total (nT)
B_x (nT)
B_y (nT)
B_z (nT)
133.0
133.5
134.0
134.5
135.0
doy of 1995
B_z (nT)
B_y (nT)
B_x (nT)
22.5
22.8
23.1
23.4
23.7
24.0
HCS crossing on May 12, 1995 (hours)

HYT(0.36,0.91, -0.22)
MVA(0.09,-0.25,-0.96)
with λ_2/λ_3 = 14.5

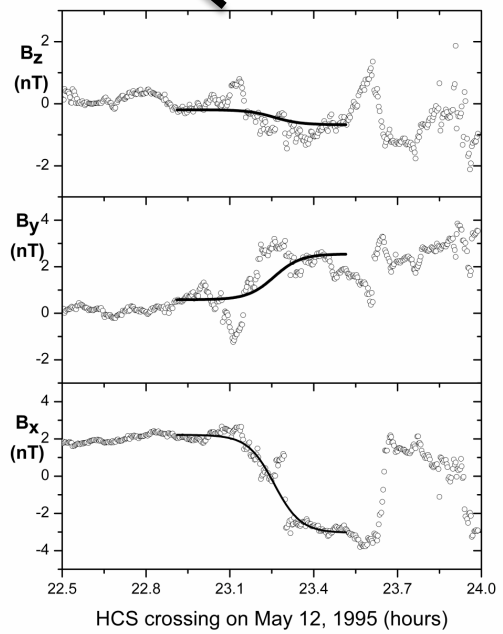
No well connected with neutral line

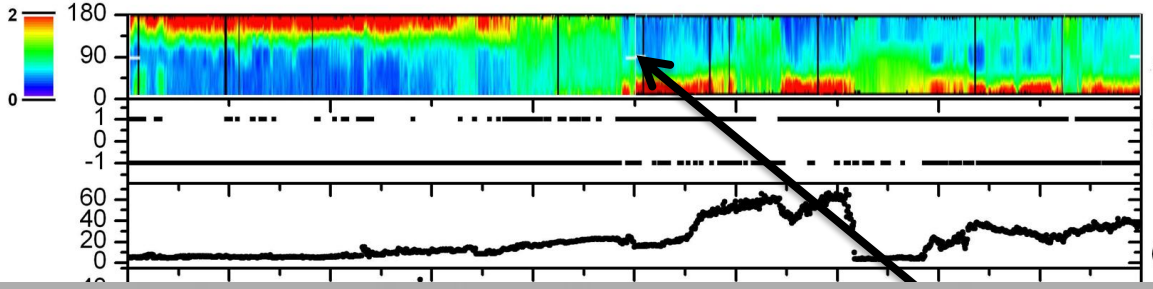
But +-27 days
HYT(0.95,0.17,0.26)
MVA(0.92,0.01,0.39)
And
HYT(0.61,0.15,0.77)
MVA(0.61,0.06,0.74)





Elapsed time: 11h
MC axes (-0.95, 0.29, 0.1)
Helicity +
MC speed 330 km/s
HCS-SW speed 340 km/s



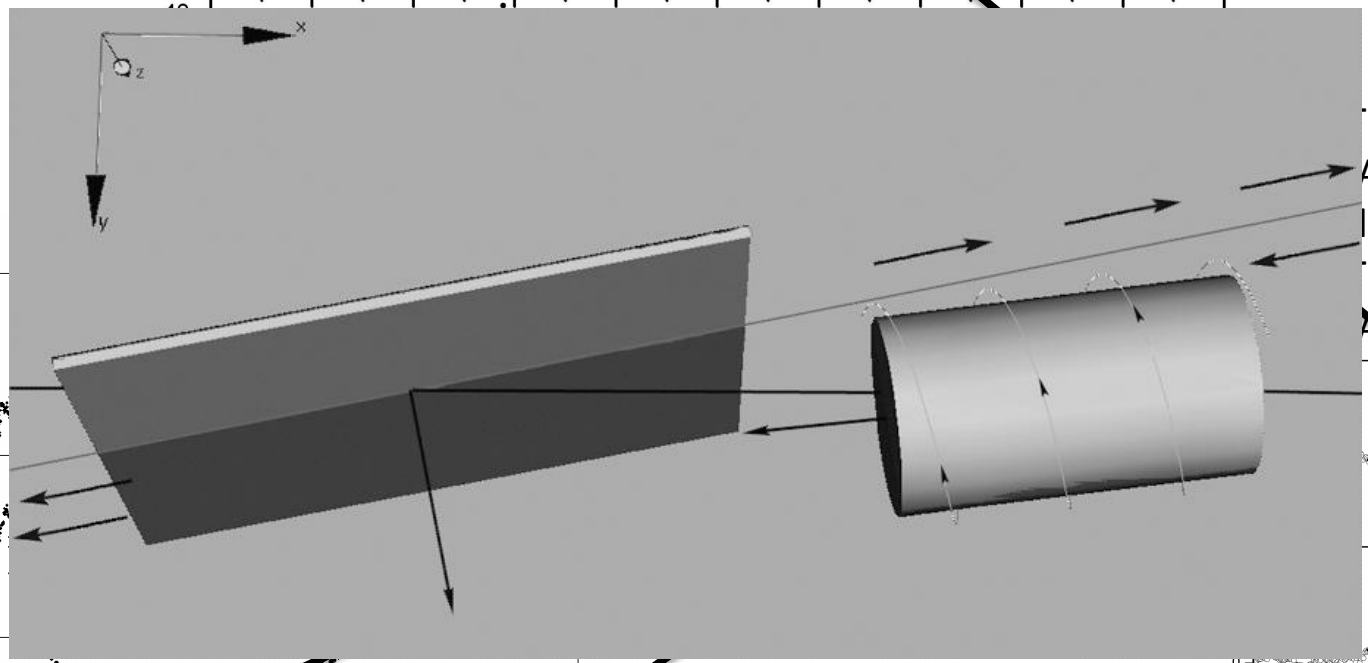


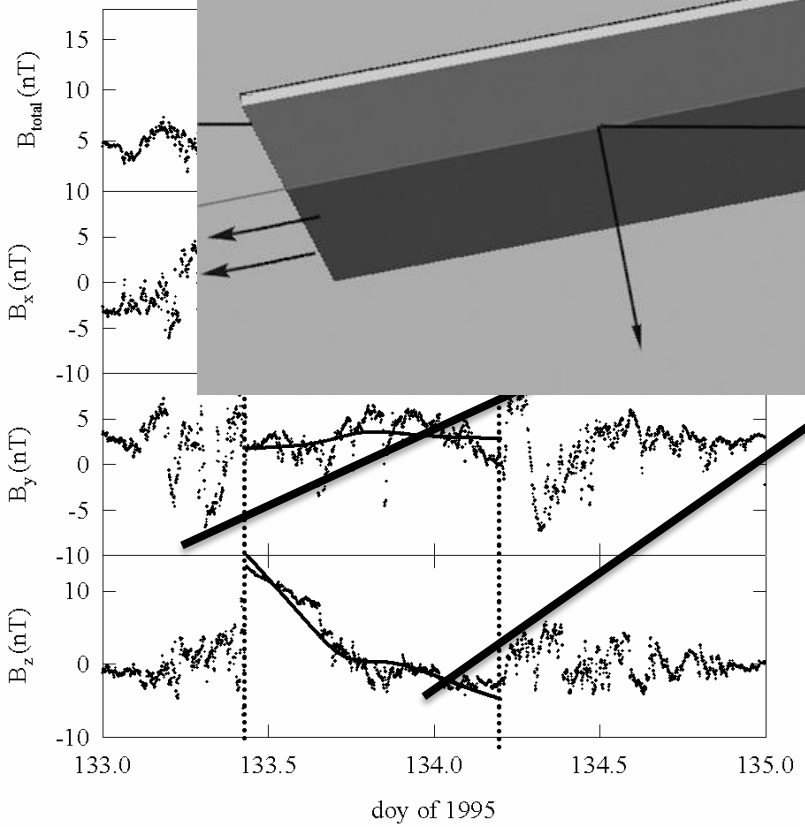
HYT(0.36,0.91, -0.22)
MVA(0.09,-0.25,-0.96)
with λ_2/λ_3 = 14.5

No well connected
with neutral line

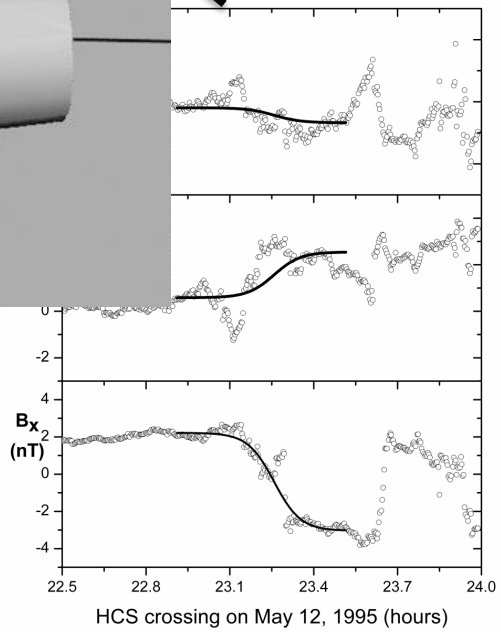
+-27 days
(0.95,0.17,0.26)
A(0.92,0.01,0.39)

(0.61,0.15,0.77)
(0.61,0.06,0.74)

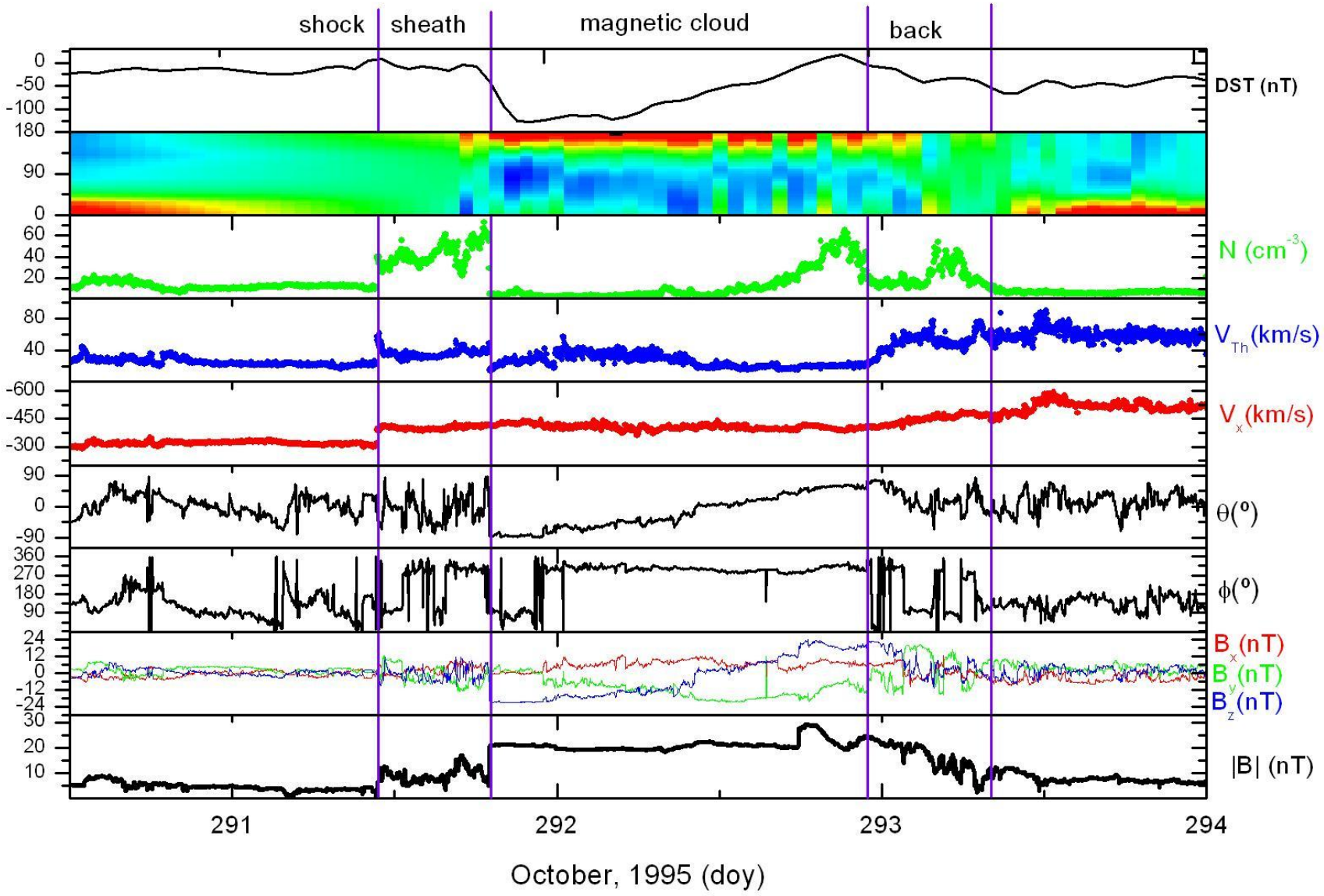


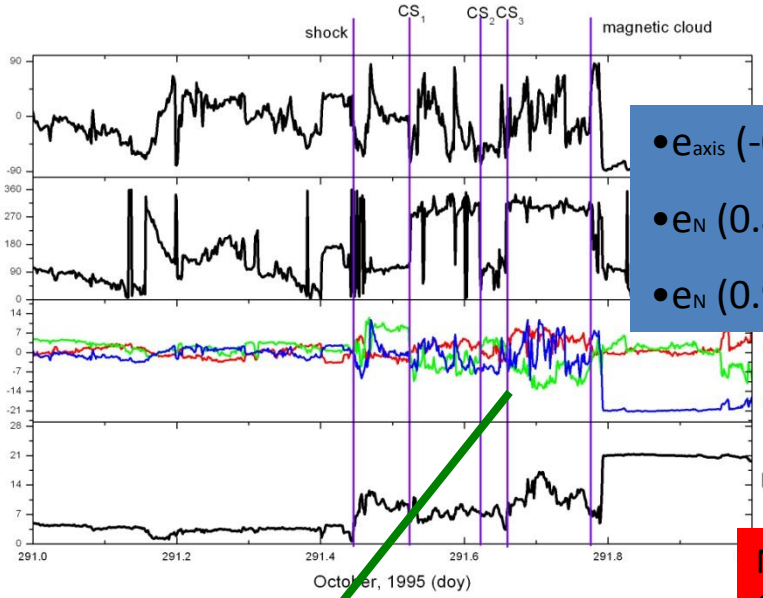


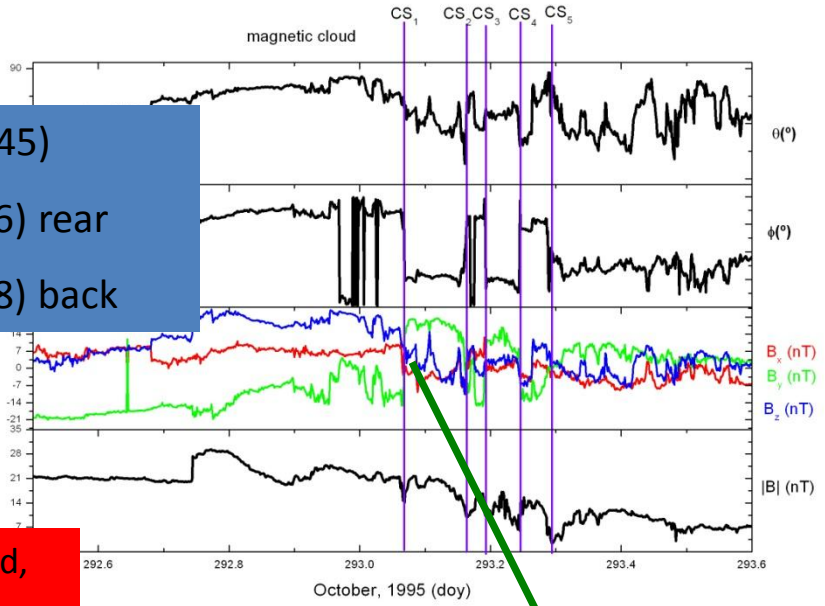
MC axes (-0.95, 0.29, 0.1)
Helicity +
MC speed 330 km/s
HCS-SW speed 340 km/s



MC and HCS crossing: Example 3

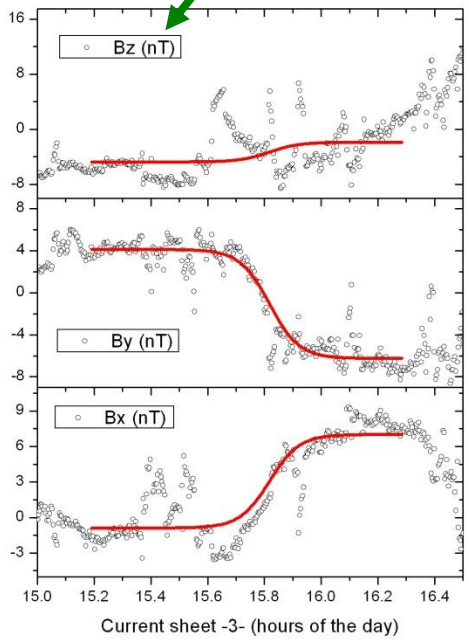


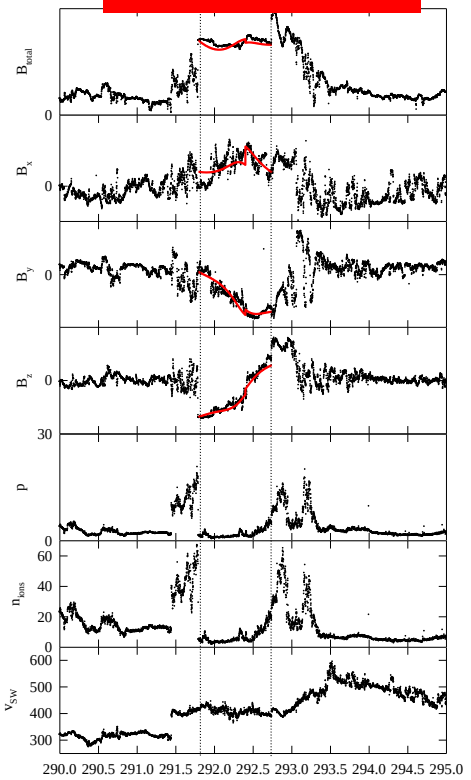


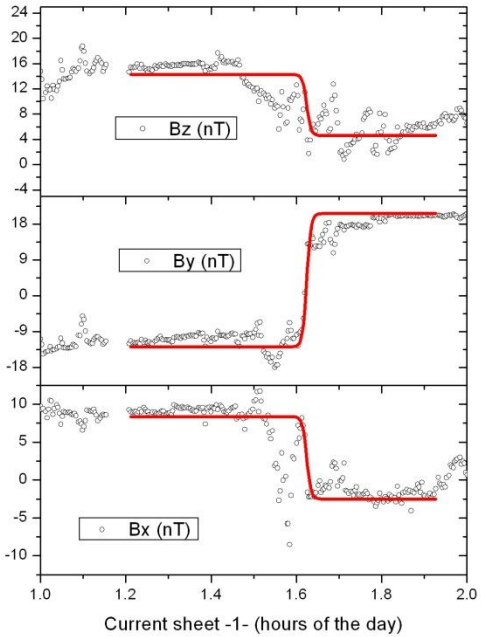


- e_{axis} (-0.79,-0.4,-0.45)
- e_N (0.81,0.57,-0.16) rear
- e_N (0.96,0.27,-0.08) back

Magnetic Cloud, October 1995







Journal of Atmospheric and Solar-Terrestrial Physics 73 (2011) 1339–1347

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Interaction between magnetic clouds and the heliospheric current sheet at 1 AU as it is observed by one single observation point

J.J. Blanco*, M.A. Hidalgo, J. Rodriguez-Pacheco, J. Medina

Space Research Group, Dpto. Física, Univ. Alcalá, Alcalá de Henares-Madrid, Spain

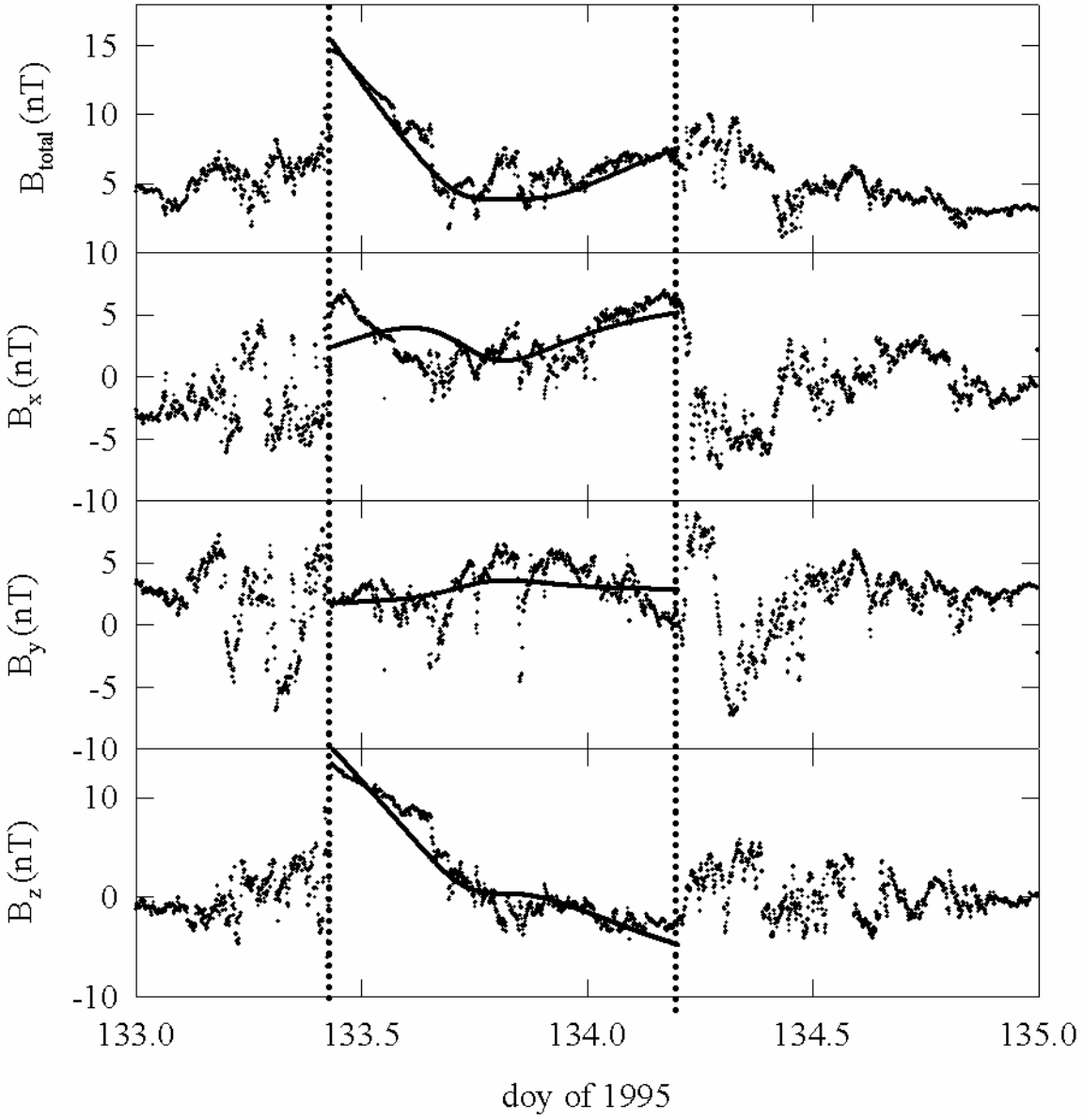
ARTICLE INFO

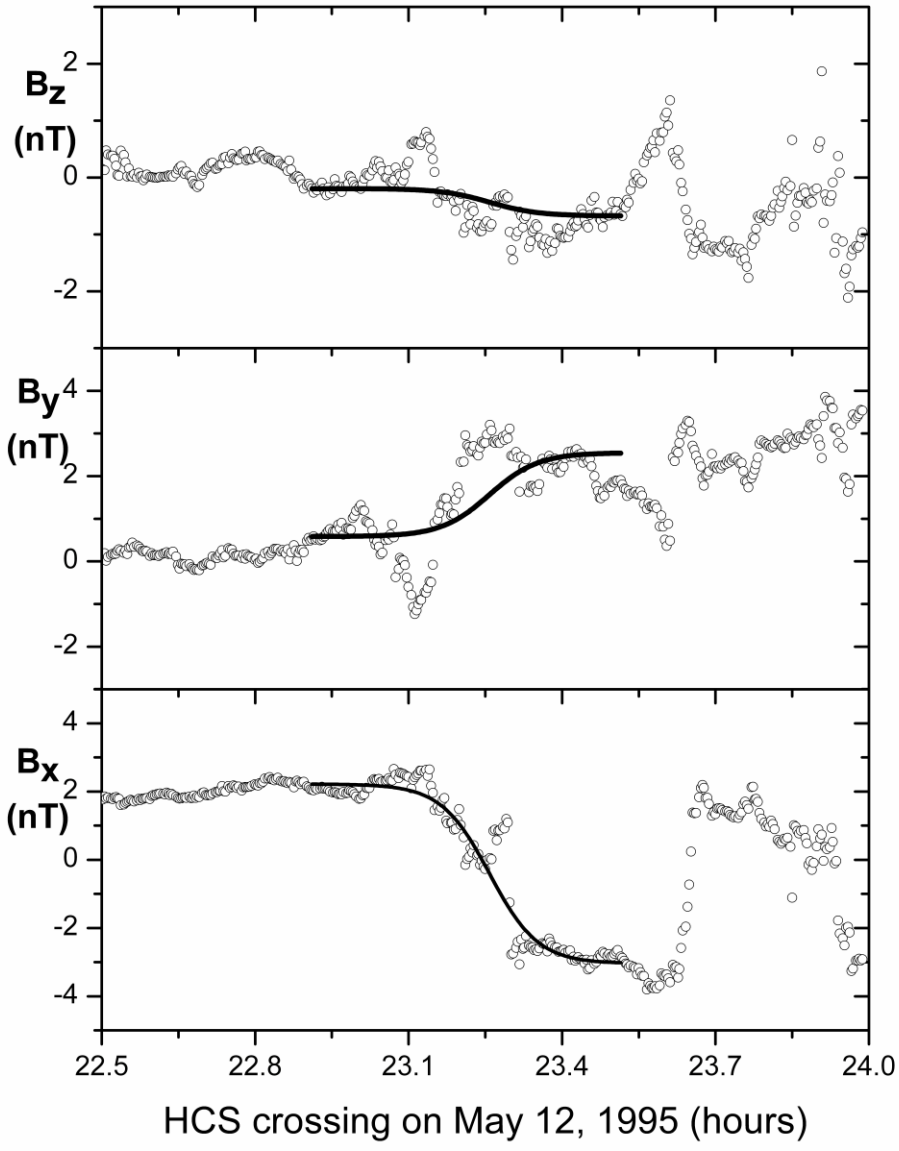
Article history:
Received 9 March 2010
Received in revised form
22 October 2010
Accepted 25 October 2010
Available online 3 November 2010

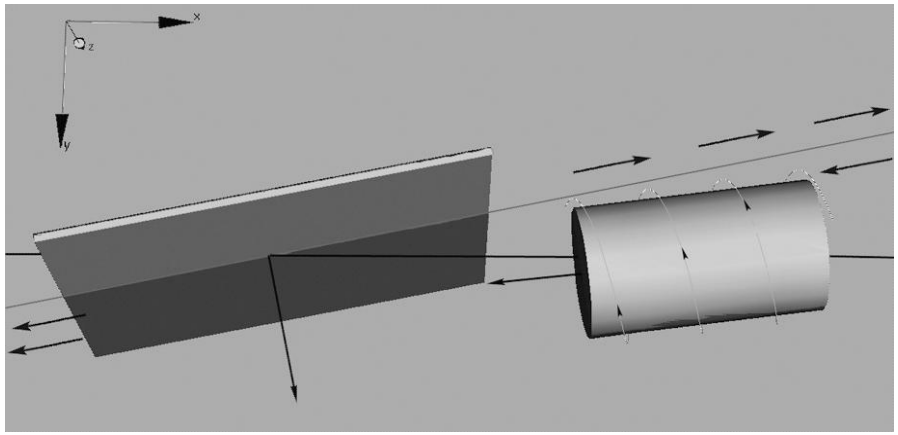
Keywords:
Magnetic clouds
Heliospheric current sheet
Solar wind

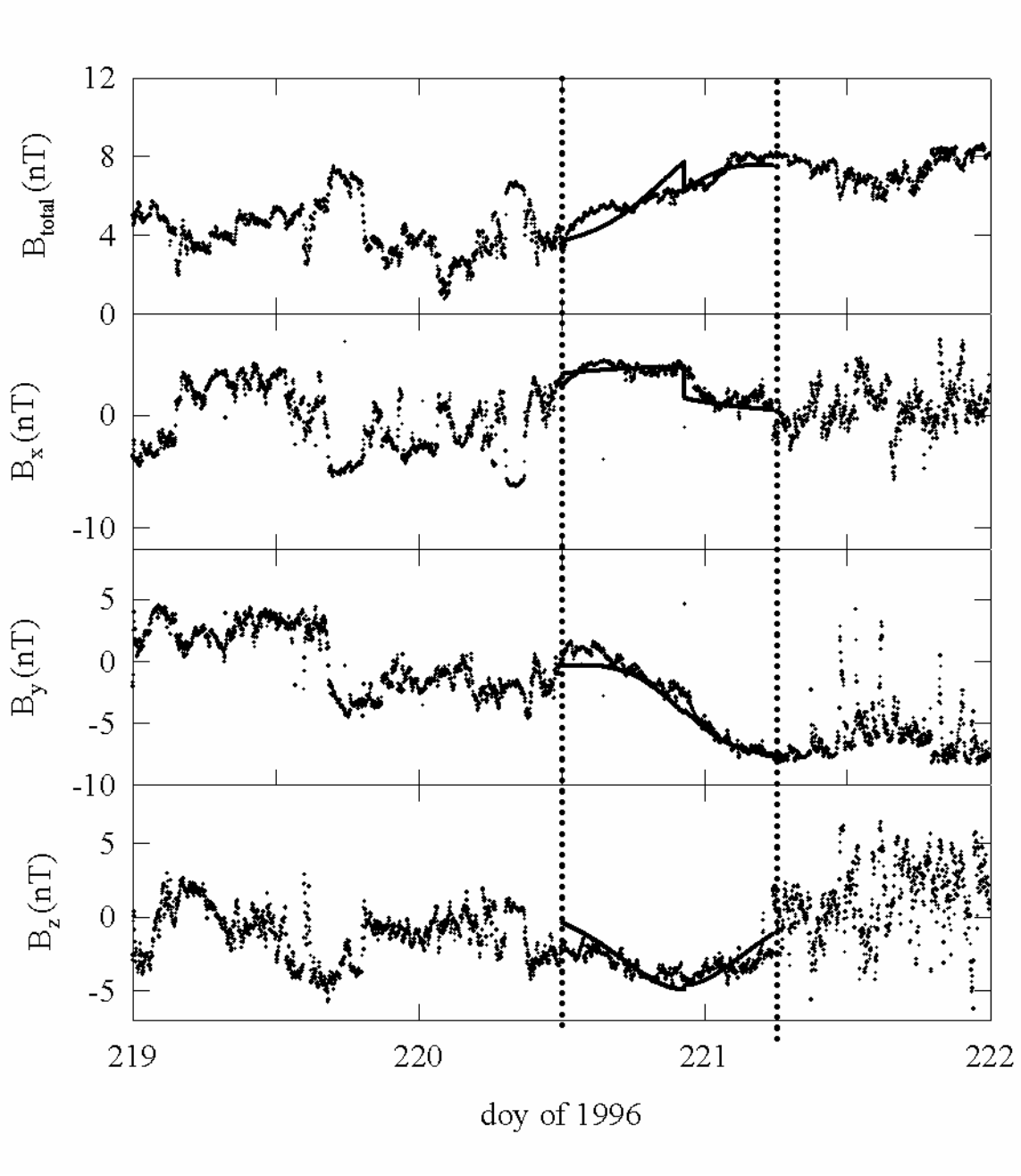
ABSTRACT

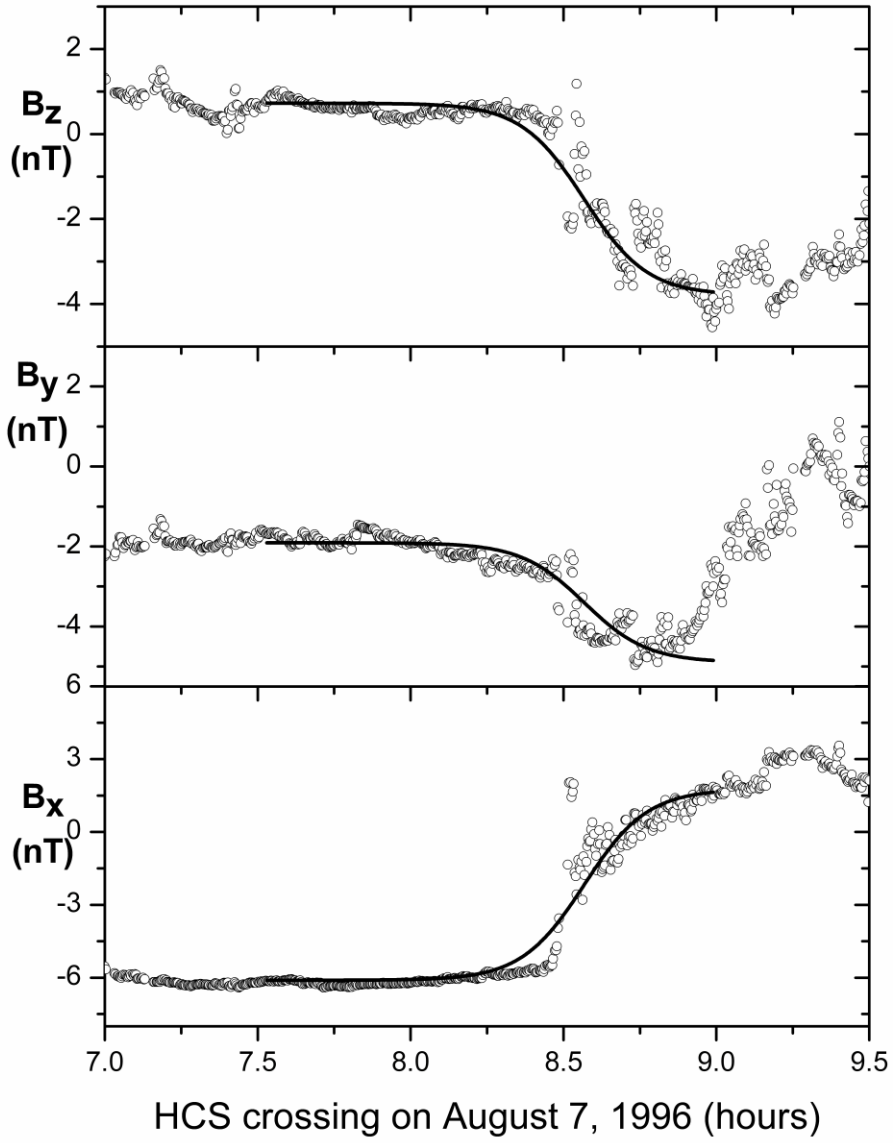
The effect of Magnetic Clouds (MCs) on the Heliospheric Current Sheet (HCS) local structure is yet an open question. Although it is widely accepted that a magnetic cloud has an important effect on the HCS shape, their structural relation, either the MC is part of the HCS or not, is not completely solved. Moreover, the problem grows up when trying to investigate three dimensional structures using one single observation point. We propose an approach to the MC–HCS study using magnetic models for the MC and local HCS structures, which are able of determining their relative orientation from one single spacecraft data. Three events have been selected in which an MC passage was observed close to HCS crossings. The results confirm the strong effect of MC passage on the HCS local orientation and they seem to be consistent with MCs propagating out of the HCS at 1 AU.

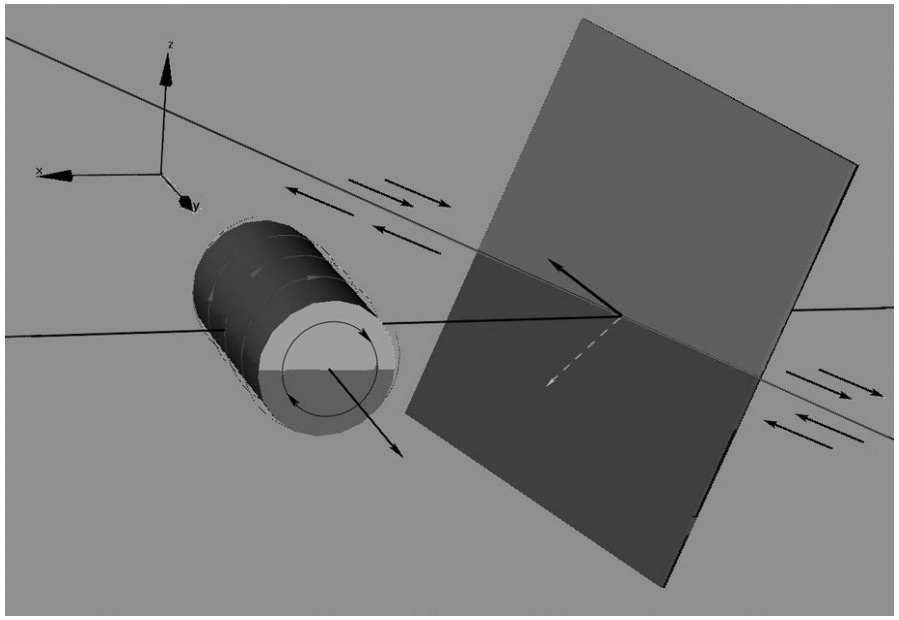

15
10
5
10
B_{total} (nT)
5
0
-5
-10
B_x (nT)
5
0
-5
-10
B_y (nT)
10
0
-10
B_z (nT)
133.0
133.5
134.0
134.5
135.0
doy of 1995


B_z (nT)
2
0
-2
B_y (nT)
4
2
0
-2
B_x (nT)
4
2
0
-2
-4
22.5
22.8
23.1
23.4
23.7
24.0
HCS crossing on May 12, 1995 (hours)


x
z
y


12
8
4
0
B_{total} (nT)
0
-10
B_x (nT)
5
0
-5
-10
B_y (nT)
5
0
-5
B_z (nT)
219
220
221
222
doy of 1996


B_z (nT)
B_y (nT)
B_x (nT)
2
0
-2
-4
6
3
-3
-6
7.0
7.5
8.0
8.5
9.0
9.5
HCS crossing on August 7, 1996 (hours)


z
x
y